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Facsimile Cover Sheet

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Pages including this cover page: 12

Brian:

Attached is ~~the~~ updated provisional patent information for the inventions as they relate to the surface modifications. I will also be emailing the written material

I will be continuing on the other concepts but this is probably 50% of the material.

Roger

Brian Note added ¶ & Fig 1n, — 1r

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Elastomeric interconnection Concepts

Introduction

As electronic systems get smaller, faster and lower cost the classic methods of separable interconnection need to be replaced with new technologies. One such technology is based on anisotropic conducting polymer materials. Anisotropic Conducting Elastomers (ACE) are elastomers which conduct in one direction but are insulators in the other direction. One such example is ECPI – (Elastomeric Conducting Polymer Interconnect) a material developed by Lucent Technologies – Bell Laboratories. This material is formed by magnetically aligning fine magnetic particles in sheets of uncured silicone such that the particles form arrays of electrically isolated columns. These columns are frozen in place as the silicone cures. When a layer of ECPI is compressed between two electrical conductors the particles in the compressed column come into contact with each other and the conductors forming an electrically conductive path. Conductivity of the column remains over a compression range which is a function of the material design. This range, often referred to as the materials dynamic range, provides compensation for the lack of coplanarity of the conductors. This is often referred to as "coplanarity compensation".

In a typical application of ECPI the interconnect formed replaces the soldered interconnect to allow a separable interconnection. This can be required for testing the device, aging the device (burn-in) and for final application in the OEM product. One such example is in a Land Grid Array (LGA) where an array of pads on a device needs to be connected to a matching array on a board. A second example is when a Ball Grid Array (BGA) consisting of a device with an array of solder balls is to be separably connected to a matching array on the board. In both of these examples a layer of ECPI material placed between the device and the board can, when properly used provide a reliable connection.

Although ACE materials have been demonstrated to work in these applications, there are several unique improvements that can enhance their ability to perform reliably. These improvements are to the polymer materials, the surface geometry of the material and to the connectors housing the material. These improvements are the subject of this patent application.

Elastomeric Patentable Concepts

The ECPI material developed by Lucent Technologies' Bell Labs was designed primarily for interconnecting pad to pad type interconnections such as the Land Grid Array. Although the materials function well in this area they have limitations which can be improved by the introduction of novel concepts. These limitations are as follow.

The outer particle layers can be removed during cleaning or handling. This will result in a loss of continuity. This is particularly true in the case of Plasma etched material where the surface of the material has been etched to better expose the particles so that more intimate contact with the pads can be made. The delicate

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nature of the surface can limit the use of the elastomer both in applications and number of recycles.

- When using the material as an interconnection medium between BGA devices the spherical shape of the solder balls can bow the columns of particles outward from the contact center rather than compressing in straight paths (figure 1d). This can result in poor interconnection and shorting between adjacent pads. Elastomeric materials tend to behave like incompressible fluids. This means that as the material is compressed there must be space provided close to the point of contact for the material to flow in order for the column of particles to make contact with each other, the device and the board.
- Conventional pin-in-socket contacts provide for a metal to metal wiping action as the pin mates with the socket. This wiping action breaks through surface contaminates and corrosion products such as oxides and sulfides. This is critically important to providing a low resistance connection. Elastomerics provide little or no wipe. Penetration of unwanted contaminates must be facilitated by the nodular structure of the particle at the surface of the elastomer. This can result in a variability in the materials performance.
- The material surface of the pad must be properly matched to the material that it contacts on the particle. A solder pad against a gold plated particle can result in the gold dissolving in the solder and forming a brittle alloy which will break and form a type of insulating layer referred to as *fretting corrosion*. The existing ECPI materials are plated with gold or silver which are not well matched to solder.

The above list of limitations to the capability of conventional elastomeric conducting material can to varying extent be applied to both anisotropically conducting elastomeric materials that have magnetically aligned particles and isotropically conducting materials such as those that are heavily filled with conducting metal. It can also be applied to some extent to anisotropic elastomeric materials that utilize other means than the magnetic alignment of particles to provide electrical and/or thermal connection.

Several inventions are proposed which can be used individually or in various combinations to address the above described limitations. These are described below with figures provided as needed.

1. **Integrated Surface Pads**

Figure 1a provides a conceptual cross section of the typical elastomeric conductor using magnetically aligned particles. This picture indicates the thin layer of polymer material that remains on the surface after manufacturing. This layer is penetrated by the particles as the material is squeezed between pad layers. Figure 1b shows the surface material etched away in a manner taught by patent xxxxxx. The particles are now quite fragile and the material must be handled carefully to prevent the particles from dislodging. Figure 1c presents the next stage in the process and the present invention. In our invention the elastomeric material has an array of conducting pads (and other structures) formed on the surface in intimate contact with the surface and in a preferred embodiment in contact with the surface particles as shown in Figure 1c. This pad array can be formed by sputtering, vapor deposition, plating or a

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combination of these methods that are well understood by those skilled in the metal surface formation industries.

The resulting pad(s) form a bond between the silicone and the surface particles which protects the surface particles and keeps them from dislodging. Furthermore, the pad forms an extended electrical contact area for reliably providing electrical contact. This geometry is particularly well suited for interconnection to BGA devices. Each solder ball on the BGA will now contact a matching pad on the silicone which is tied to the surface particle of several particle columns as indicated in Figure 1c. The resulting structure will now compress straight as with the LGA eliminating the bowing of the columns induced by a spherical solder ball.

Although the figure indicates pads formed on both surfaces of the elastomer, it is envisioned that pads and conductors can be formed on one or both surfaces and to be able to create a multiplicity of electrical paths as indicated in Figure 1c to augment the routing provided by the device and board.

The pad structure provides a readily cleaned protective layer greatly increasing the usable life of the material. Furthermore, a secondary cleaning operation of the plasma etched material with integral pads will remove the surface particles from unwanted areas while leaving the only in the pad area. This will minimize the opportunity for unwanted electrical contact.

The pad thickness of the pad layer provides a space between adjacent pads for the incompressible polymer to flow as the material is compressed. This allows the elastomeric material to be used in applications where no local expansion space is provided such as with designs using solder mask around the lands causing the lands to be depressed relative to the surface of the solder mask.

The pad surface can be structured so as to optimize the interconnection to the opposing member. It's surface finish can be solder, gold or any material that is an optimum match of the opposing member. Different finishes can be provided on opposing sides of the elastomer pads to facilitate the interconnection of normally inappropriate materials such as solder to gold.

As stated above, sharp aspirates are needed to puncture oxide layers and to provide a quality interconnection. These can be provided on the pad surface in a number of ways.

- If the pad is thin relative to the surface particle the particle's form will protrude through the plating as indicated in figure 1f.
- By utilizing a secondary plating operation to form dendrites as taught in IBM patent xxxxx or diamond shards as taught in patent xxxxxx aspirates can be formed as needed. Figure 1g schematically indicates the appearance of these aspirates
- Chemical or Mechanical methods such as etching and sand blasting will roughen the base metal of the pad surface while having little effect on the surrounding elastomer. A subsequent thin plating of a hard metal such as nickel followed by a

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thin surface plate will provide an ideal surface which is well populated with aspirates as indicated in Figure 1h.

A very robust and easily cleaned surface is needed for the maximum cycle life needed in the device test arena. The pad layer on the elastomer provides a durable conductor surface. The elastomer surface in between the pads can be coated with a debris resistant film such as a flexible solder mask which will be easily cleaned.

In another embodiment, the elastomeric material is constructed in a manner indicated in figure 1j. In the normal construction of elastomeric conductive sheet a carrier film such as a 0.005" thick layer of Mylar is used to carry the elastomeric film through the manufacturing process. This carrier sheet is normally removed from the elastomer at the end of the assembly. In this embodiment the normally used carrier sheet is modified by the addition of a thin support film as indicated in figure 1j. This film would have holes formed in it on the pattern of the contacts. In one design it could be a 0.002" thick film of Kapton with 0.025" holes formed on 0.050" centers. Other features such as registration and mounting holes could also be formed in the Kapton sheet.

When the elastomer is formed it will fill the holes in the support film. When the carrier sheet is removed from the support film as indicated in Figure 1k a structure consisting of elastomeric conductor and support film as indicated in Figure 1e remains. The support film seals the surface of the elastomer and provide additional dimensional stability to the structure. The exposed pads can now be etched and plated as described earlier with aspirates as needed. The resulting structure as shown in figure 1m provides a stable, sealed surface which can be readily cleaned. This will facilitate repeated use such as that done with test sockets and burn-in sockets.

In another preferred embodiment the structure shown if figure 1j – l m has 2 support films as shown in 1n or a modified carrier sheet as shown in 1p. When these films are removed a small gap is left between the surface of the ACP pad and the surrounding area as shown in figure 1q. This serves two purposes: it allows the ECPI to access lands which are surrounded by solder mask and are depressed relative to the solder mask (figure 1r) and it also provides a place for the elastomer to flow to during compression. The protruding pads may or may not be metalized as described earlier based on the application. new

Although the example indicates pads on one surface only the concept can be extended to provide pads on both surfaces with the support film on one or both sides of the elastomer. The concepts described above can be combined in several ways to address the interconnection needs of a specific application. Having read this disclosure, these combinations are obvious to one normally skilled in the art.

2. Separabl Surface Pad

There are several applications where it is advantageous to having the pad layer as a separate structure or applique which would b mounted on top of the ACE. The applique

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would be aligned relative to the device and board but the ACE would not require orientation relative to the pad layer. Figure 2a shows such a structure. With this structure the pad would serve as the interface between the ACE and the device contact. The ACE would provide the needed compliance to allow for interconnection between the components.

One preferred embodiment of the applique would consist of a non conductive sheet such as Kapton which has holes formed on the same grid as the contact array. These would be populated by small floating contact pads such as those depicted in figure 2b. These contacts would have a diameter comparable to the land or solder ball diameter. And a height of ~0.010 to0.020". They would have a reduced diameter section "waist in the middle which would allow them to be captured in the hole in the Kapton. The compliance of the Kapton would allow for the pads to be snapped into the hole but would retain the pad under normal conditions. The pad could move up and down the length of the waist while being held in place laterally. These contact pads could be machined from metal such as brass using a screw machine tool and barrel plated with gold or solder. They also could be molded from plastic and plated to create the conductive path. The plating process would start with an electroless copper plate and be followed with nickel and solder or gold as needed. These plating techniques are well known to those skilled in the art of plating. The mold insert would have a roughened surface in the area which generated the pad contacting surface. This would result in the needed aspirates to penetrate the surface films.

In another embodiment, shown in figure 2c, the contacts described above are also molded out of plastic. In this embodiment the contact would also be formed with molded aspirates in the contact areas. Also the shape could be optimized to match the opposing contact. An integral molded lead frame would mechanically orient the plurality of contracts such that they were held on the contact grid thus eliminating the need for the Kapton carrier. The contacts would be preferentially plated with the appropriate metal system to address the needs of the interconnection. The lead frame would, in it's final state, not be plated leaving it non-conductive. This can be facilitated by several different techniques.

One such technique is to use a double molding process where the lead frame and contacts are molded from different plastics. The contacts would be from a plateable plastic and the lead frame from a non- plateable plastic.

In another method the entire surface of the contact and lead frame would be plated with a thin flash of copper providing a conductive path for electroplating. A non plateable photo resist would be coated over the entire part and processed to be removed from the contact and remain on the lead frame. The assembly would be electro plated with nickel, followed by gold or solder etc as needed. The photo resist on the lead frame would be removed and the copper flash etched from the frame eliminating conductive paths. The etch would not attack the solder or gold finish on the contacts.

In another method the contact pads could be preferentially metalized by masking the lead frame and applying metal by sputtering or other form of vapor deposition.

In a preferred embodiment a Kapton carrier with holes on the component grid would be inserted into a molding press where plateable conducting contacts would be molded in each of the holes. These would have the needed geometry and aspirates formed in the mold. The resulting contacts would be electrolessly plated with materials that would not plate on the Kapton providing the needed array of contacts.

The above described concepts can be combined in numerous ways to achieve the desired geometry. One such combination would be to mold a contact pad array with lead frame

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attached. This entire assembly would plated with the techniques described . The array of contacts would be gang inserted into a Kapton sheet with matching holes. As the array is inserted, the lead frame is removed and discarded.

1. Bulk Properties (elastomer)
   A. Permanent Set with resultant loss of contact
      - Use of Silicones which are truly elastic over temperature range
      - Connector design which provides dynamic force
   B. Non Compressible Fluid Issues
      - Introduction of compressible components to provide elastic deformation
      - Form holes for material to flow
        - This works well in sheet used over device and under board as load spreader.
      - Form sheet with grid of bumps to provide space
        - bump grid can be on contact array or much finer
      - Use Materials which are both elastic and compressible (do they exist)
   C. Compressive Force vs. Displacement
      - Selection of Polymer
      - Bumps on Surface
      - Introduction of Elastically Compressible Members
2. Bulk Properties (Conductive Component)
   A. Reduce Through Resistance
      - Particle Geometry
      - Particle Surface finish
        - Plating Material
        - Silicone particle bond
3. Bulk Properties (System)
   A. Increase Dynamic Range
   B. Working Temperature

5. Connector Design Concepts
   - Add bump to rear floating double center plate.
   - Tailor back contact plate to provide contoured force distribution
6. Integrated Concepts
   - Construct polymer pads on device with magnetically aligned (or not) dots on pads – build this into lead frame. This would address test, burn in and use.
   - Construct polymer pads on board with magnetically aligned (or not) dots on board pads. (may be covered)
   - on sheet, incorporate alignment holes, plate frame.
   - Or when plating pads on sheet, precut sheet and mount it in frame with holes which serve as reference.
   - Planirization of BGA devices

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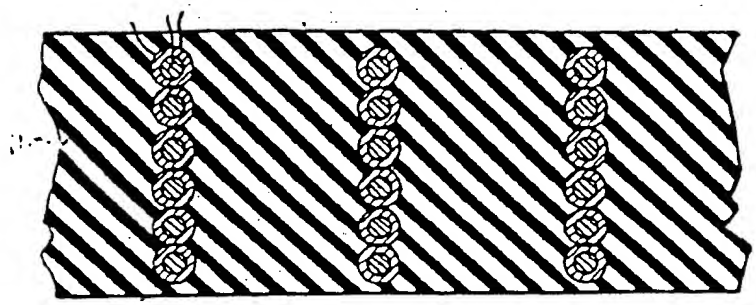

FIG. 1a
(Prior Art)

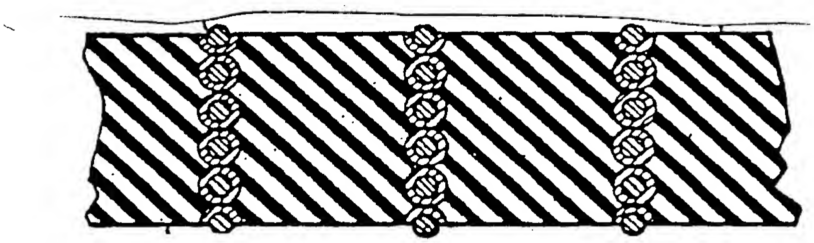

FIG. 1b
(Plasma etched)

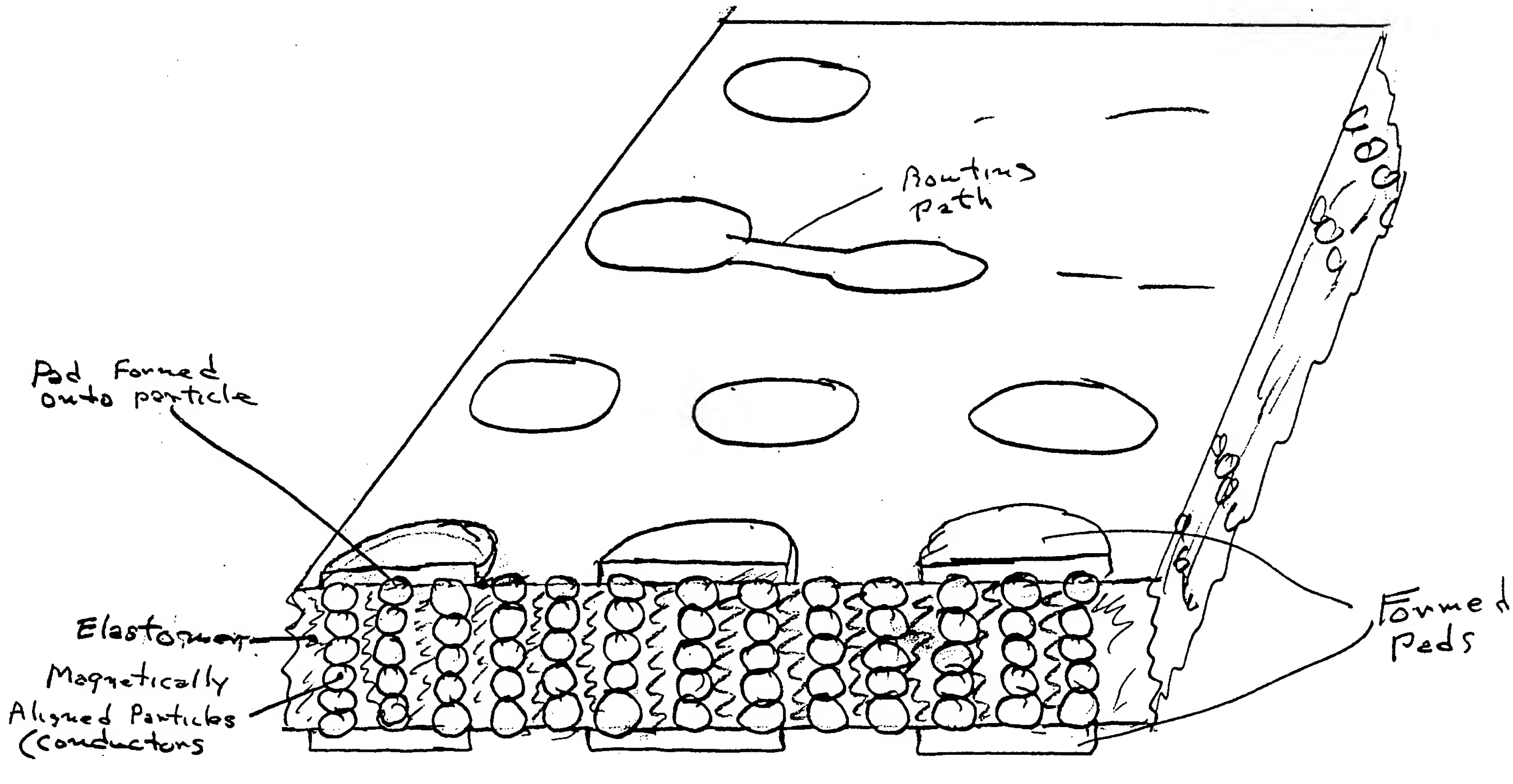

FIG. 1C
(Elastomeric Conductor with Pads)

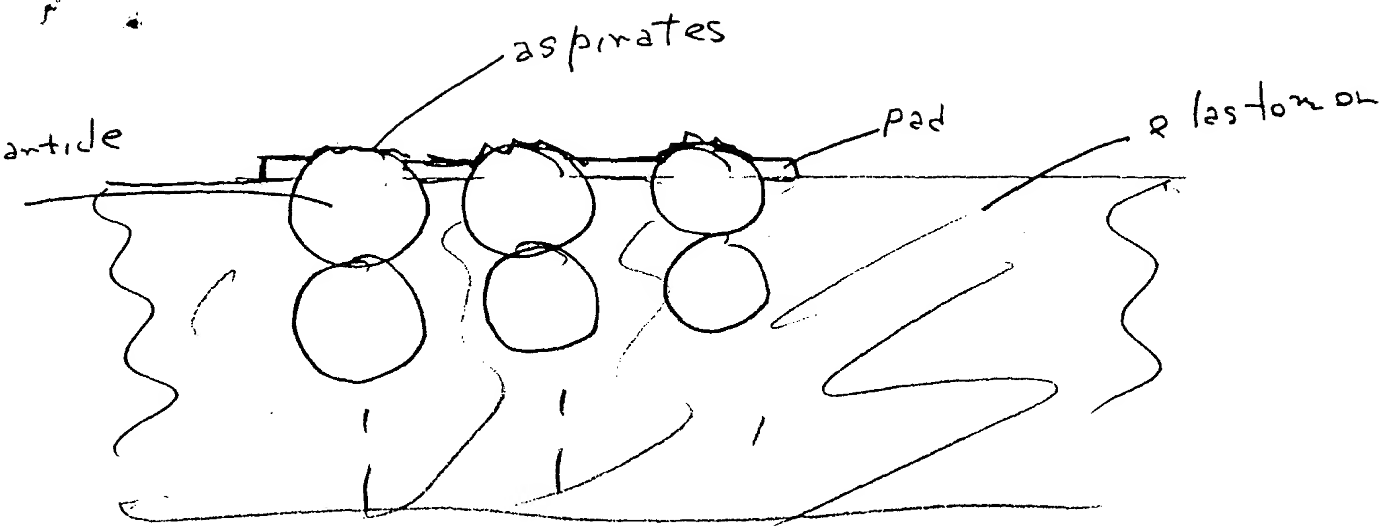

Fig 1f

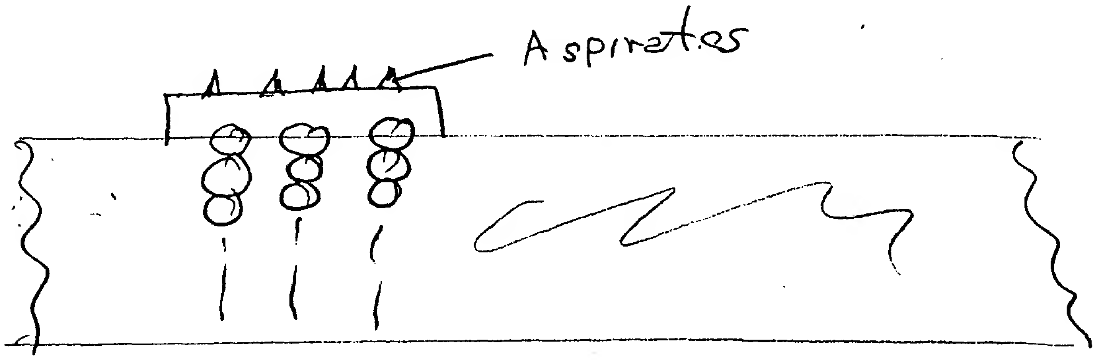

FIG 1g

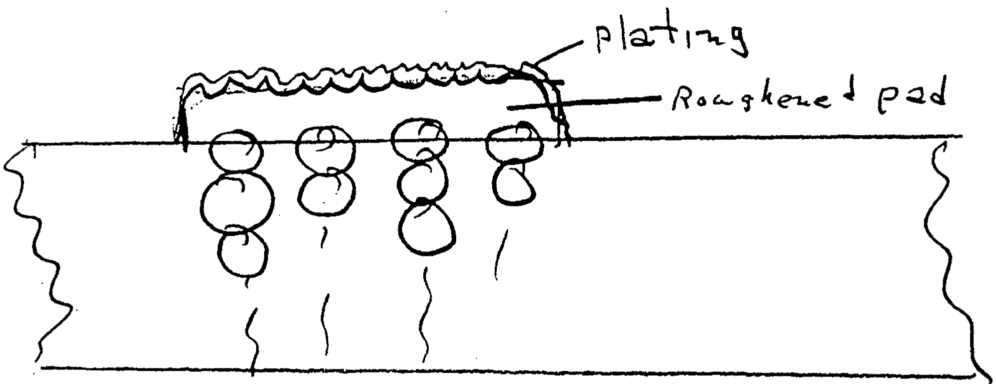

FIG 1h

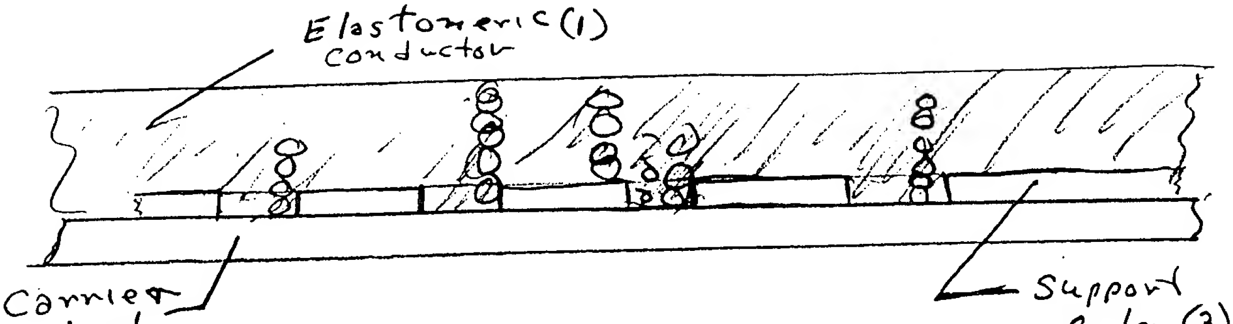

Figure 1 j

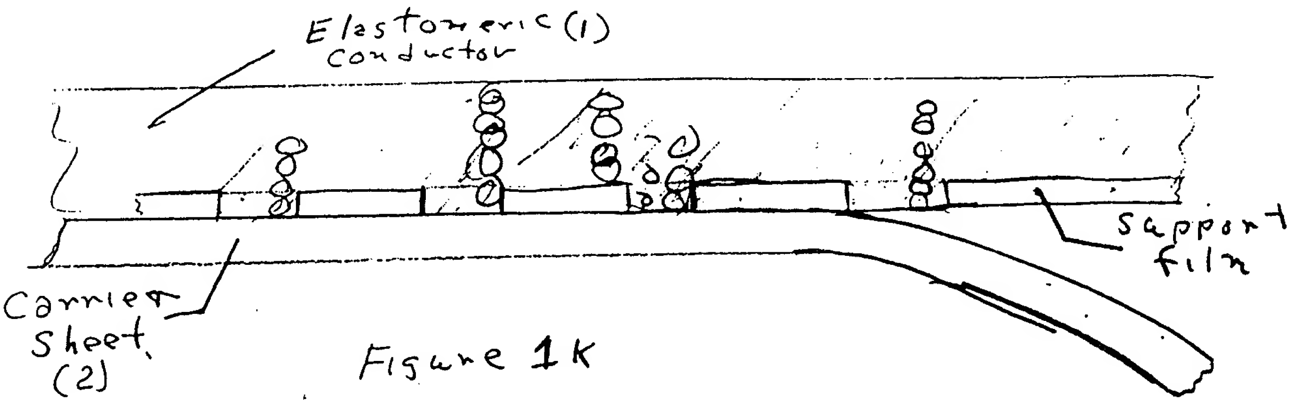

Figure 1 K

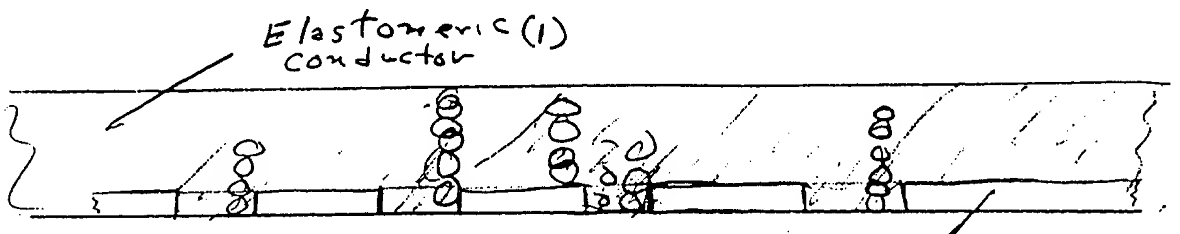

Figure 1l

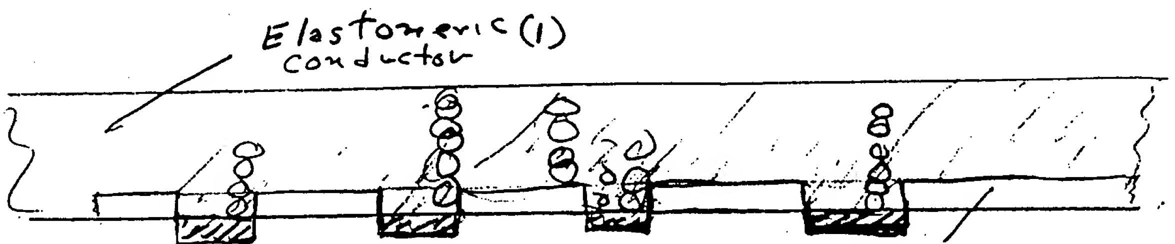

Figure 1m

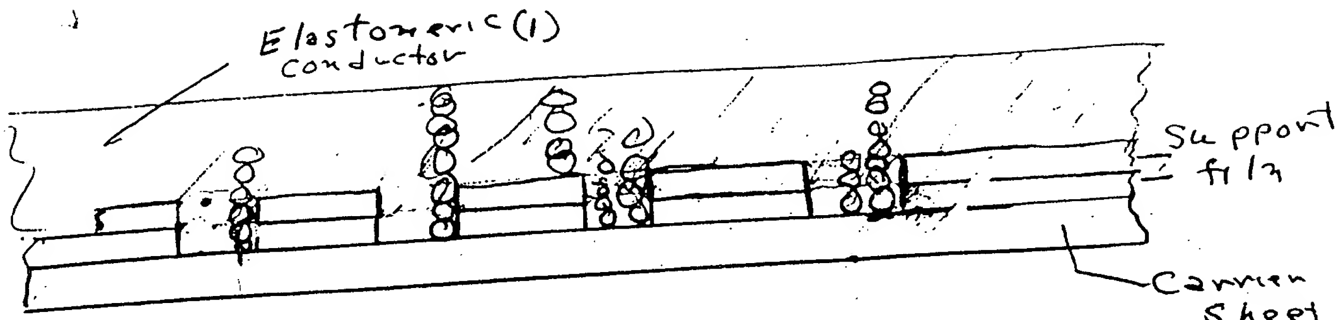

Figure 1n

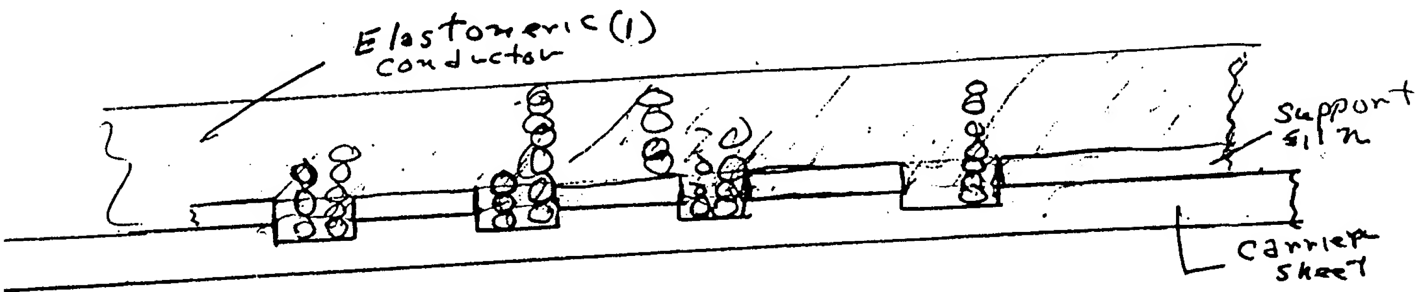

Figure 1p

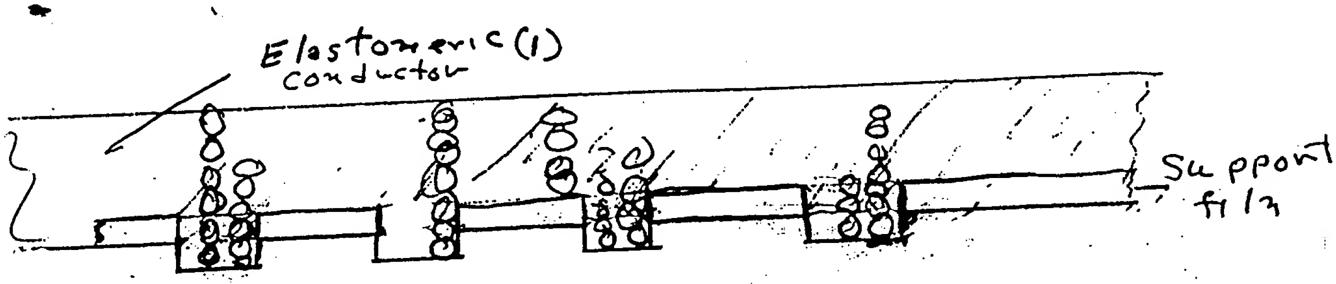

Figure 1q

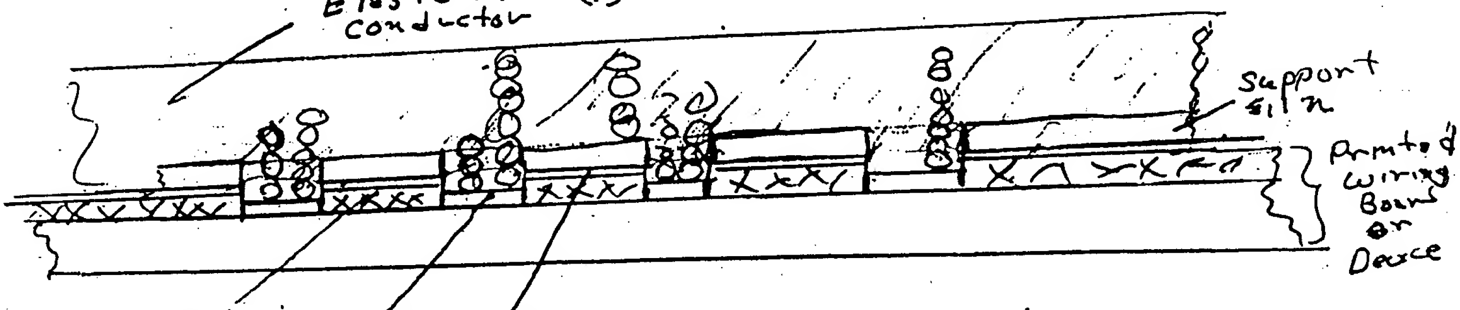

Figure 1r

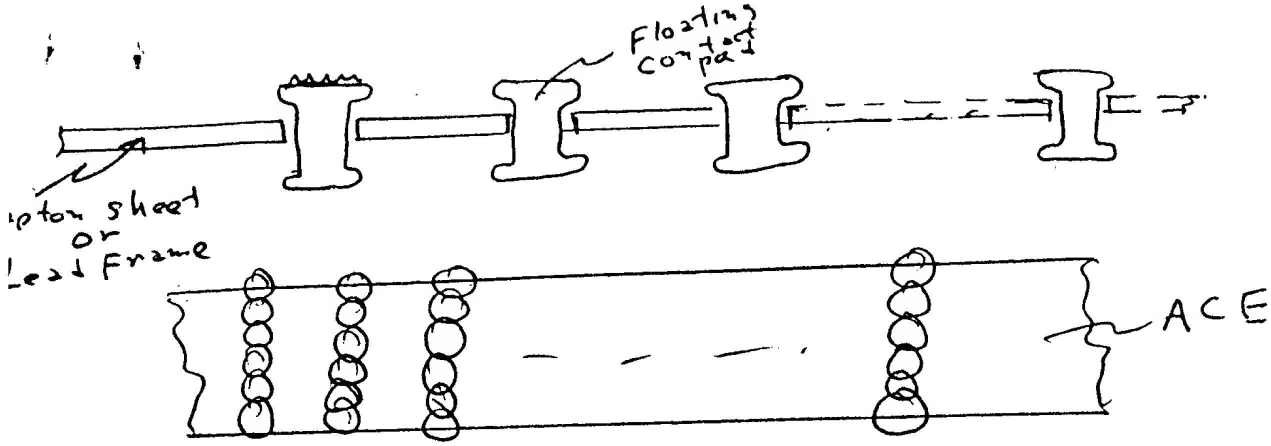

Figure 2a

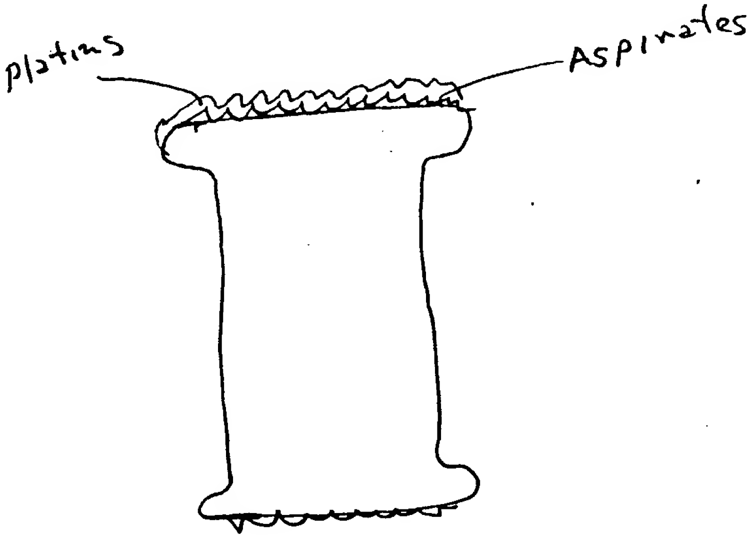

Figure 2b

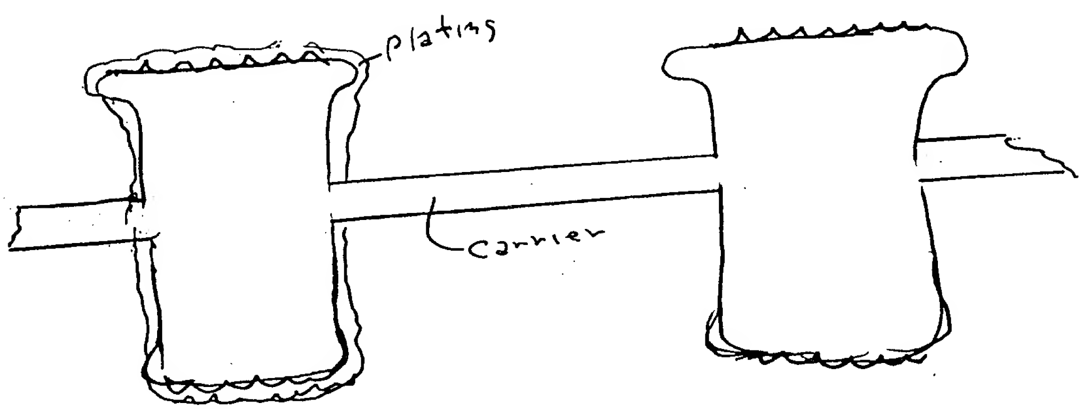

Figure 2c